Bridging Model-Based Systems Engineering and Model-Based Design

Bill Chown and Anthony Nicoli

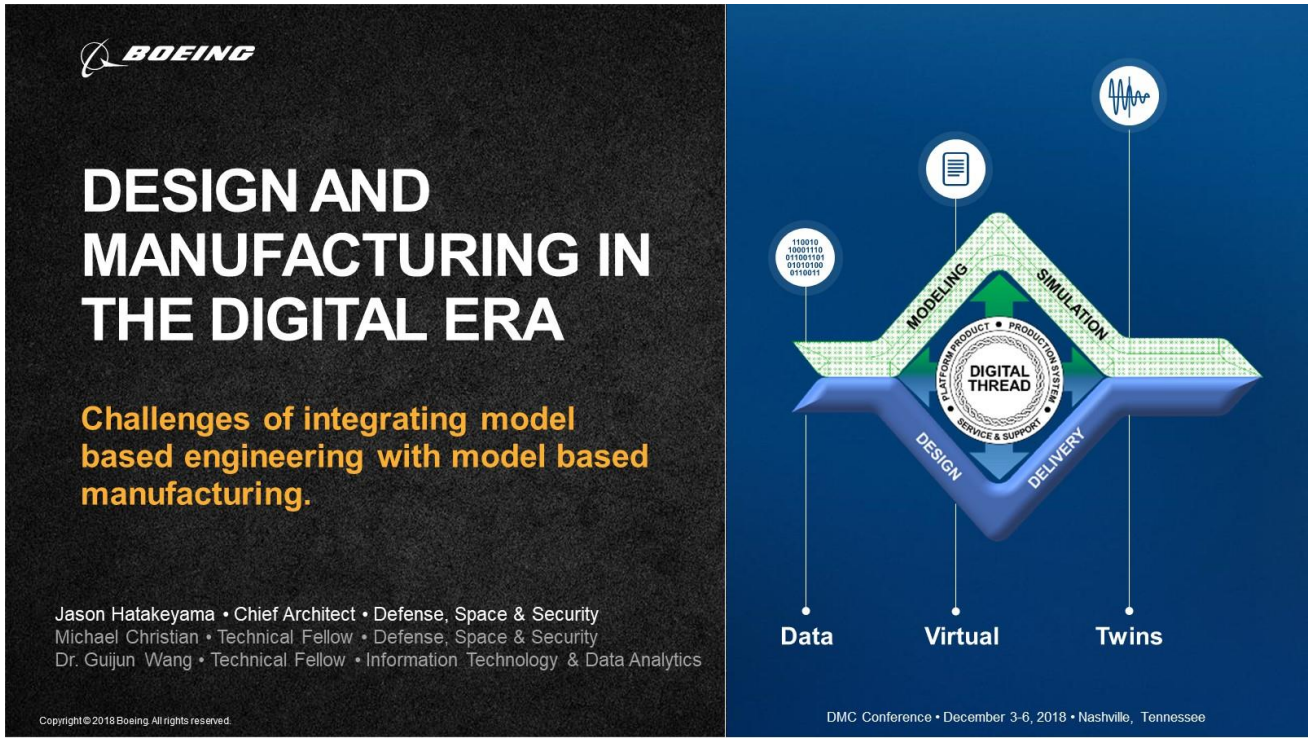
Forces Challenging Aerospace & Defense Industry Profitability

- **Winning New Business**
- **Competitive Margin Pressure**
- **Production Ramp**
- **Cost Control**
- **Just-in-Time, Quality Deliveries**
- **Supply Chain Collaboration**
- **Cost of Quality**
- **Regulatory Compliance**

Boeing $9.2B TX Trainer Win Built on Model Based Engineering & Production

Global Product Data Interoperability Summit | **2019**

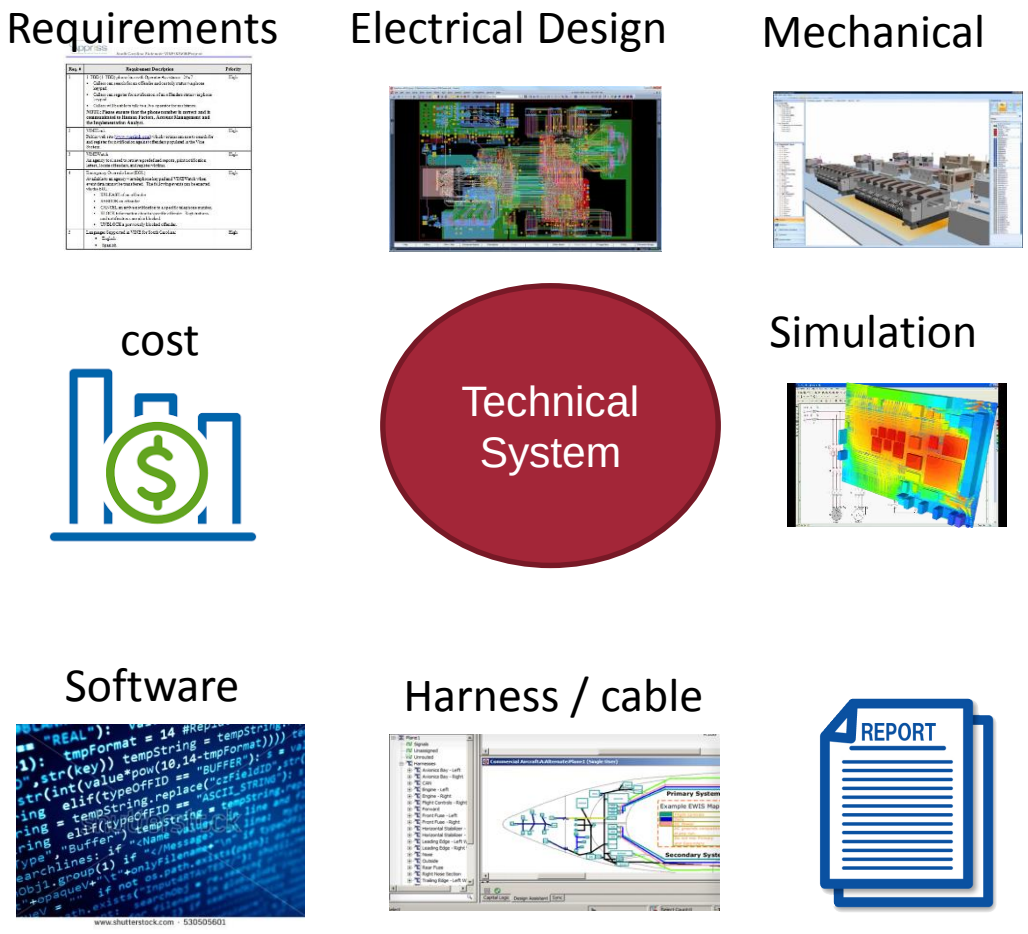
Boeing's winning bid for the T-X trainer contract came in at **least $10 billion less than the U.S. Air Force's original estimate**



Aviation Week Aerospace & Defense Daily Report "Inside Boeing's Secret Formula To Win T-X" May 17, 2019

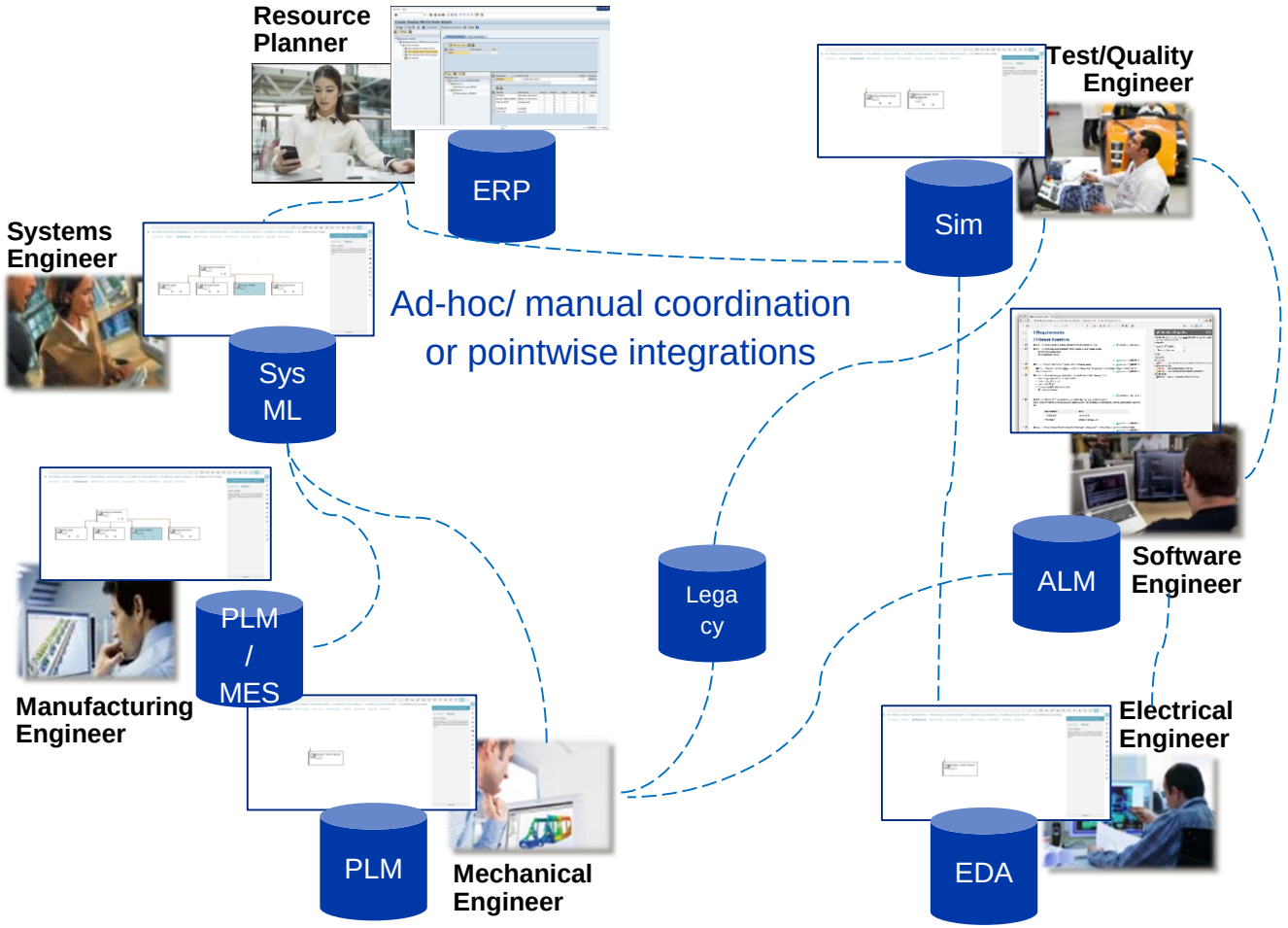
Distributed System Engineering

- **One technical system described from different perspectives**
- **One technical system, but a lot of distributed information**
- **Distributed information is challenging for collaboration**



Typical Current Landscape

Enterprise data distributed across disconnected systems

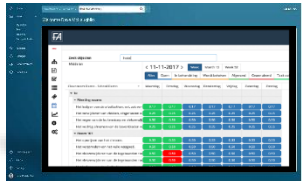


Problems with isolated information and domain silos

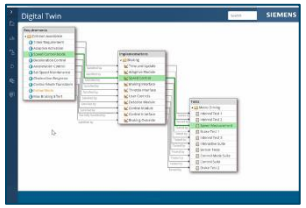
- Difficult to comprehend complete product definition
- Poor collaboration, coordination and planning
- No cross-domain traceability or dependencies
- Inconsistent versioning of artifacts
- Cannot configure data and variants across areas
- Lack of cross-domain impact assessment
- Out of date information

Integrated Business Views Across the Digital Thread

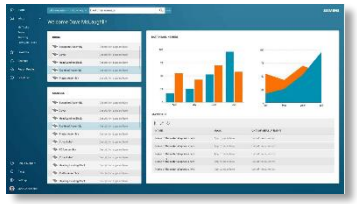
Role Based Dashboards



Cockpit Apps



Digital Thread Navigator



Digital Enterprise Cockpit

Mendix RAD for
Your Cockpit Apps

Siemens Digital Enterprise Suite

Program and Project Management, Search, Reporting & Analytics, Change and Configuration Management, Process Orchestration

Requirements Management	Systems Modeling	Mechanical	Electrical	Software	Manufacturing Planning	Manufacturing Execution	Service Planning	Performance in Field (IOT)

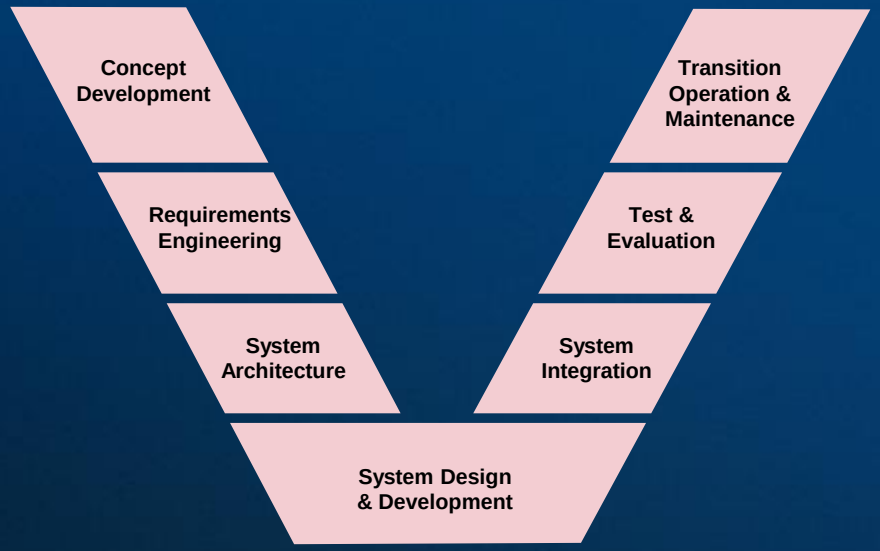
Enterprise Digital Thread

(Semantic Data Model, Traceability, Accountability, Impact Analysis)

The Requirements (from the user perspective!)

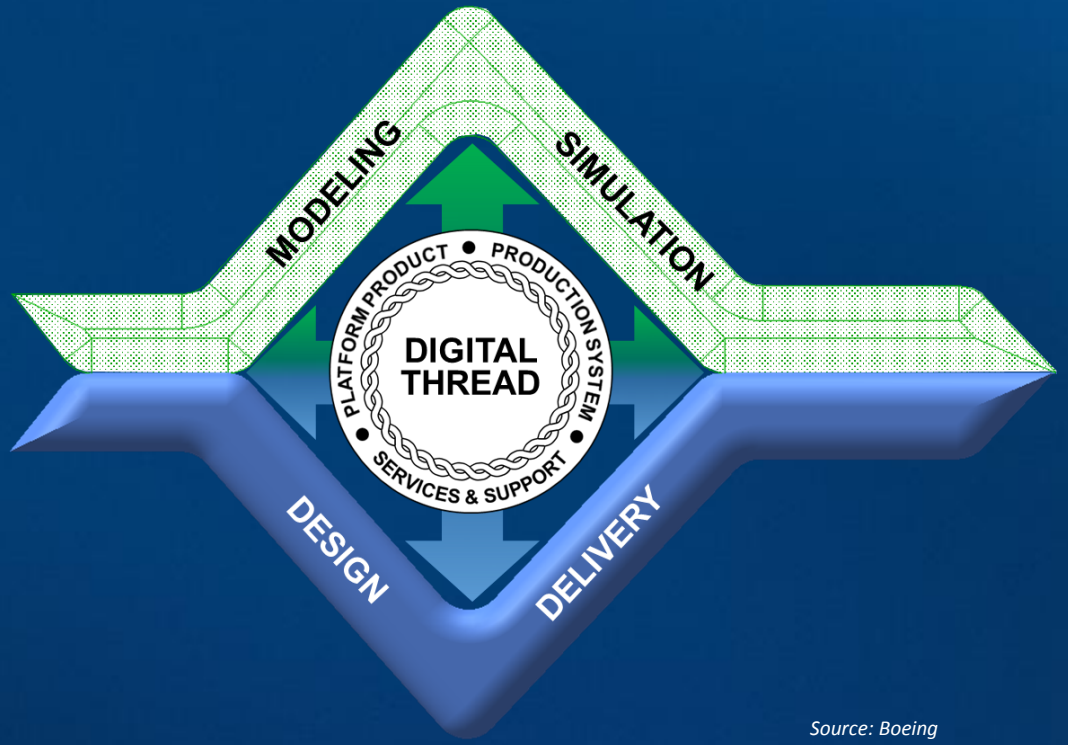
- **Changes to current practices should be minimal and incremental**
- **Every participant should have transparent access**
- **No changes should go unaddressed**
- **Incomplete work should be immediately noticeable**
- **Shared resources should be allocated effectively**
- **No work should be done twice (or more!)**
- **Every participant should access information in a familiar view**
- **Reporting upon what has been done should be no extra work**

SE V



Source: Mitre

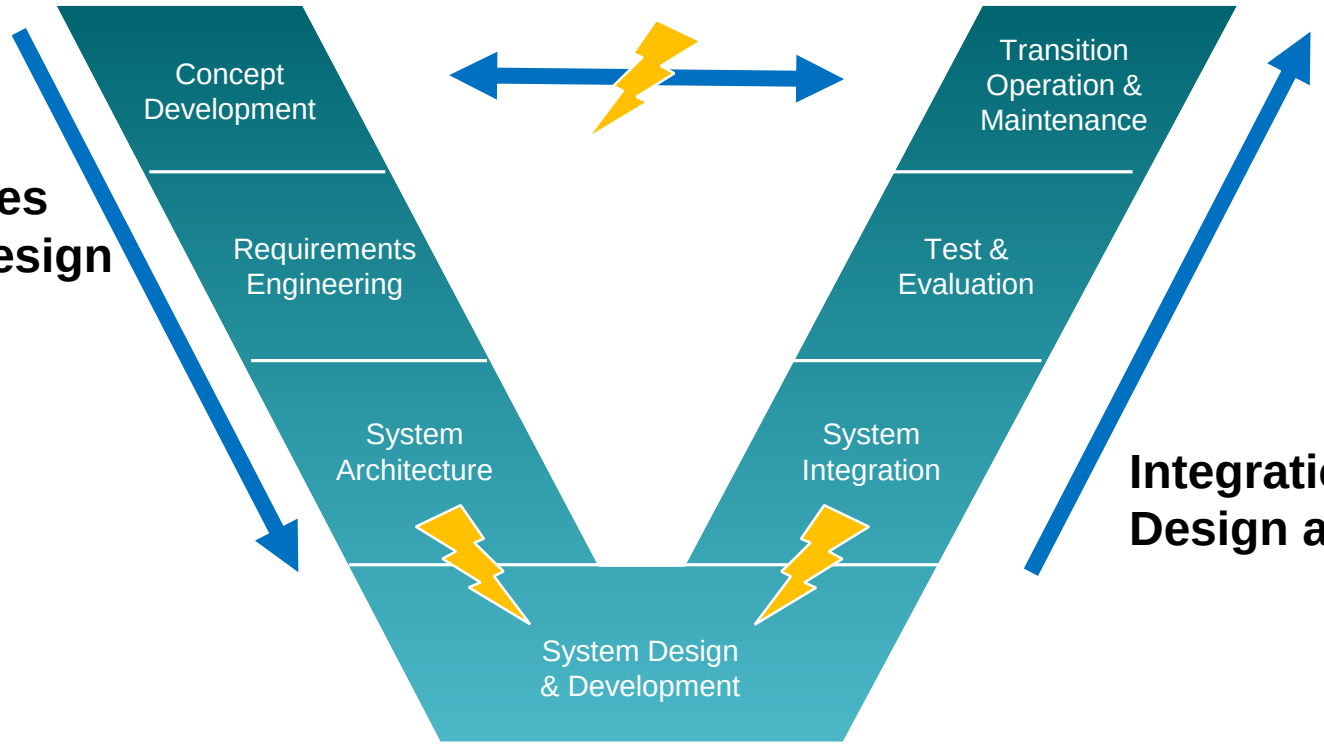
MBE Diamond



Source: Boeing

Moving from a document era to a digital engineering era with information flow across the lifecycle

Looking at the Process – the Systems Engineering 'V'



MBSE drives towards Design

Integration ties Design and SE

Model Based Design drives Implementation

Source: Mitre

Systems Engineering: Holistic Product Development

Multi Discipline Landscape

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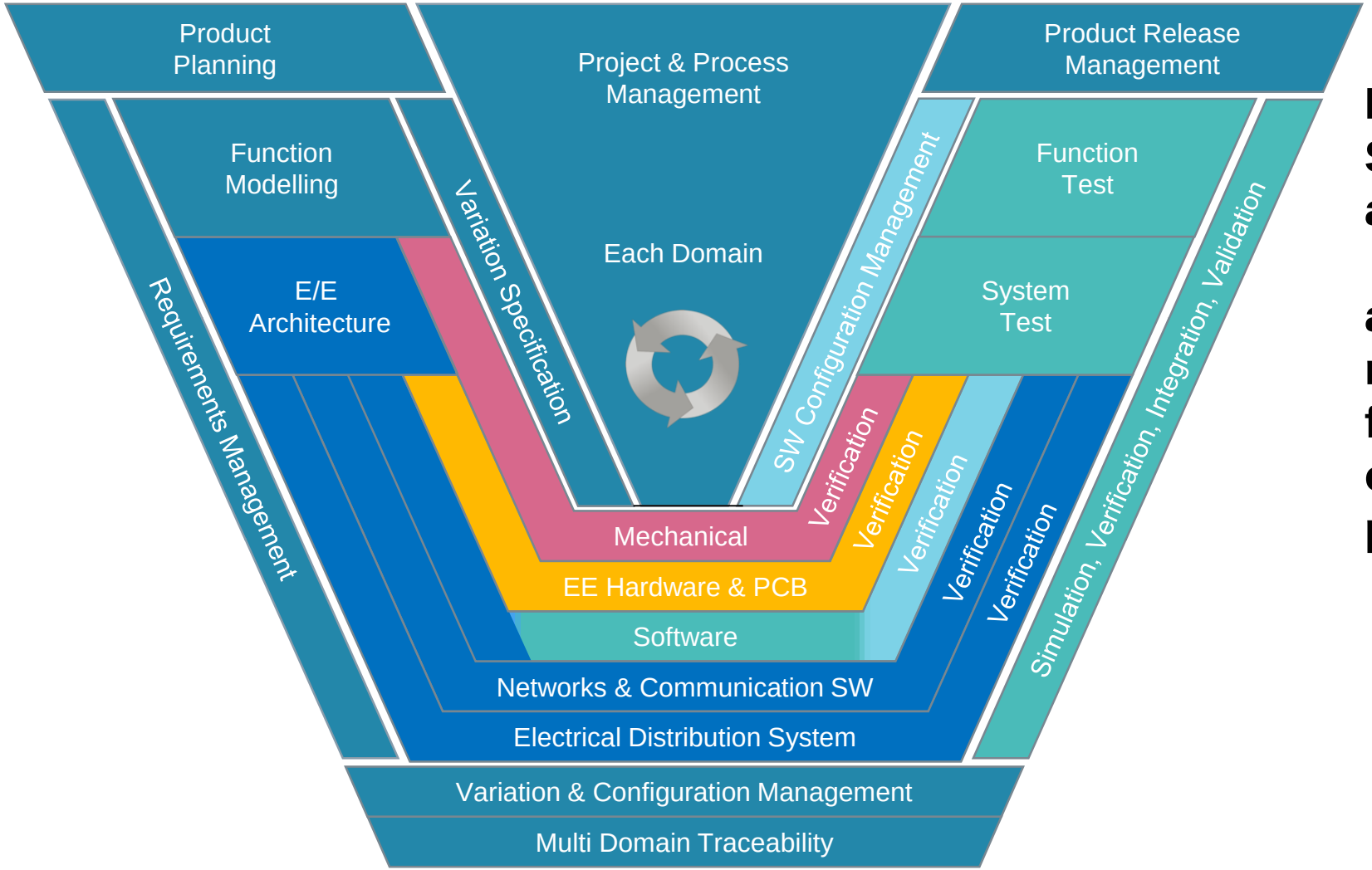

Bridging Model-Based Systems Engineering and Model Based Design

applies across multiple disciplines, flows and domains of the complex overall process

Increased Electrification Drives Power Demand

Aircraft differentiation spurs electrification

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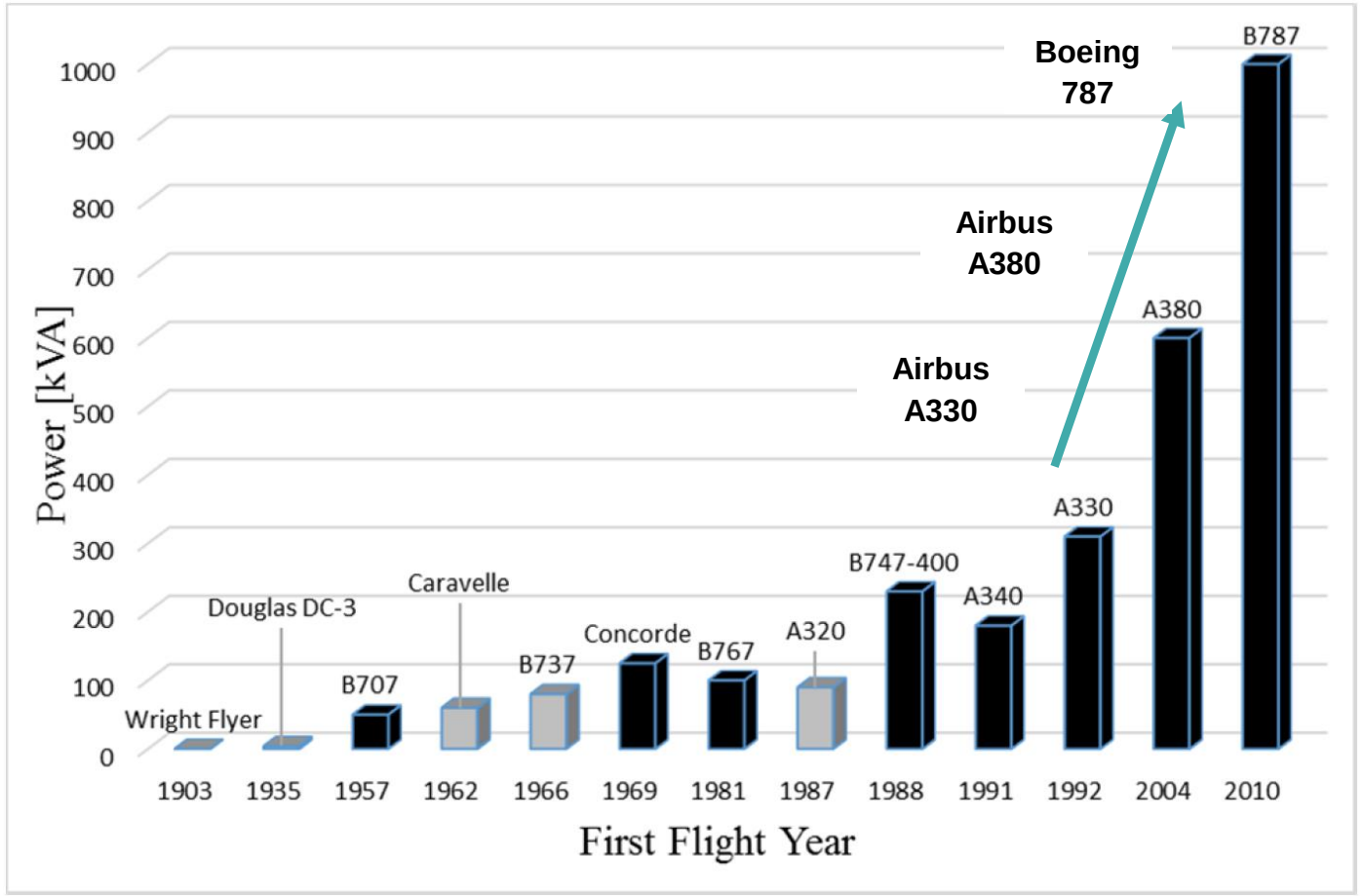
Magnitude of Impact:

25% EE Content Growth Every 5 Years

10x Power Demand Over 50 years

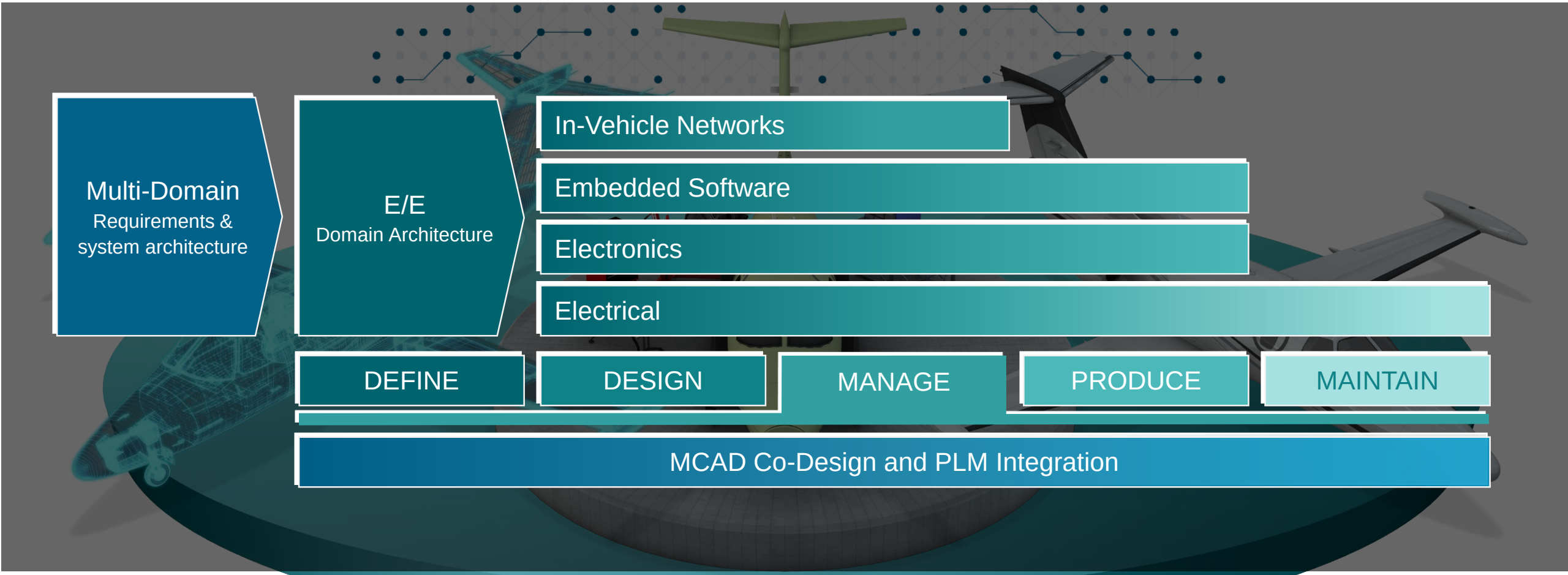
EWIS now 3% of Aircraft Weight

EWIS Cost Grows Faster than Content



Paper: “Electrical Power Generation in Aircraft: review, challenges and opportunities”
http://eprints.nottingham.ac.uk/51652/1/Electrical%20Power%20Generation%20in%20Aircraft.pdf

Model-based Electrical Systems Development Flow



Model Based Enterprise

Capital – MBSE Drives Generative & Connected Engineering

Normalizing the myriad of inputs within a common model

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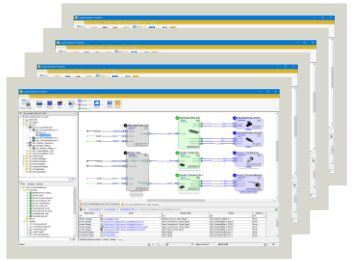
May be sourced from and integrated with PLM / ALM systems

Systems & Requirements

Continuous **Digital Thread**



Functional Models

SysML, Visio, Excel…)

Vitech · No Magic · MathWorks · IBM · SPARX SYSTEMS · PolarSys · SIEMENS

- Largely commoditized -
Value usually derived from incorporation within a downstream flow

Continuity – Traceability – Auditability through the **Digital Thread** **Digital Enterprise Cockpit**

Supported by both In-Tool and External Verification & Validation capabilities

Capital – MBSE Drives Generative & Connected Engineering

Normalizing the myriad of inputs within a common model

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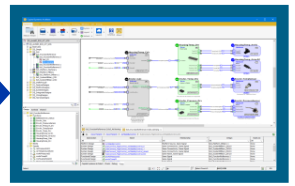
May be sourced from and integrated with PLM / ALM systems

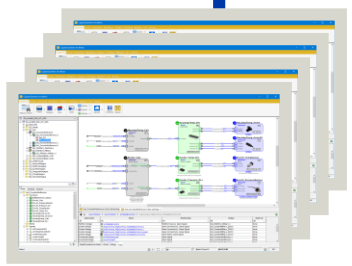
Systems & Requirements

Continuous **Digital Thread**

Normalize Functional Models within Captial

DEFINE Domain



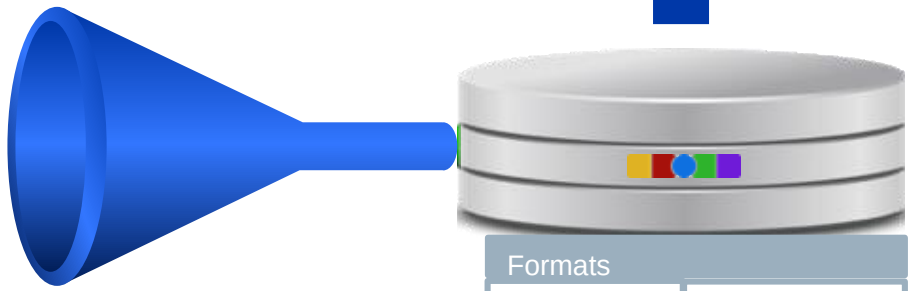


Functional Models
(SysML, Visio, Excel…)

Models captured in Capital Capture, common Data Model

Vitech · No Magic · MathWorks · IBM · SPARX SYSTEMS · POLARSYS · SIEMENS

Utilize in Downstream Capital Client Applications



Formats

✓ UML	✓ Excel
✓ SysML	✓ DBC
✓ ARXML	✓ On demand

Continuity – Traceability – Auditability through the **Digital Thread** **Digital Enterprise Cockpit**

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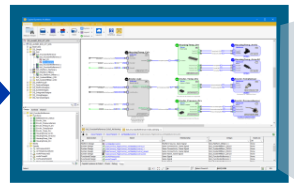
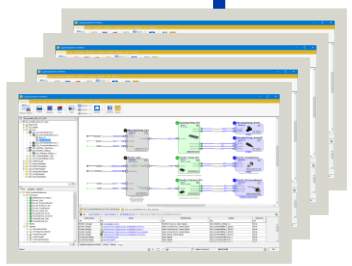
Systems & Requirements

Continuous Digital Thread

DEFINE Domain

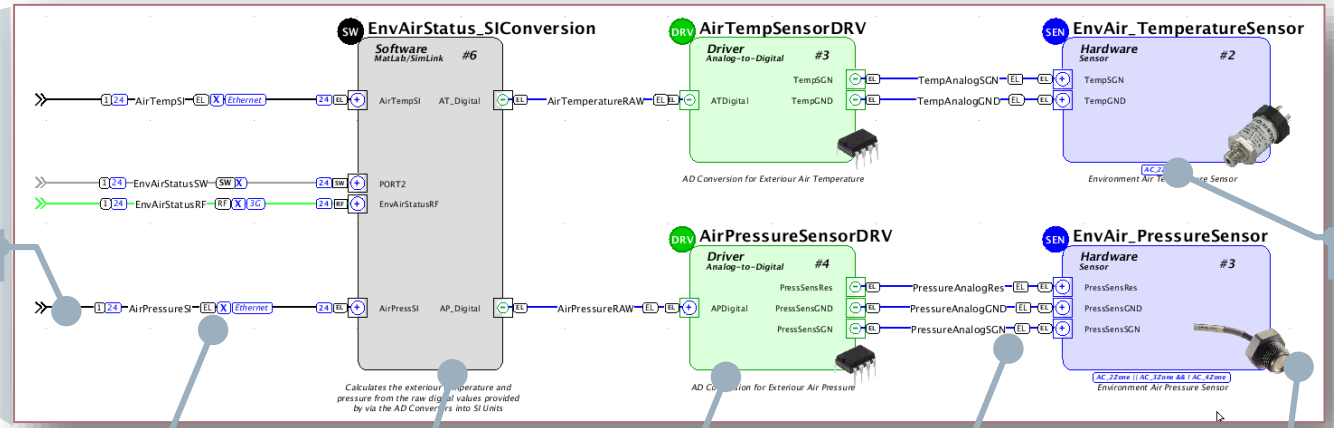
Normalize Functional Models within Capital





Functional Models
(SysML, Visio, Excel…)

Shared Signals



Option Codes

Network Signal	Software Function	Driver Function	Electrical Signal	Hardware Function
• Media Type • Multiplexed • Bit-size • Frequency • MUX Load	• SW Type • RAM • ROM • FLASH • Runtime • Frequency • CPU Load	• Driver Type • Weight • Space • Power Diss. • Heat Diss. • Cost • Power	• Electrical type • CSA • Length • Weight • Cost	• Type • Weight • Space, Height • Power • Power Dissipation • Heat Dissipation • Cost

Continuity – Traceability – Auditability through the **Digital Thread**

Digital Enterprise Cockpit

Supported by both In-Tool and External Verification & Validation capabilities

Assess Electrical System Architecture BEFORE Design

Functional Model: Validate & Optimize via Relevant System Metrics

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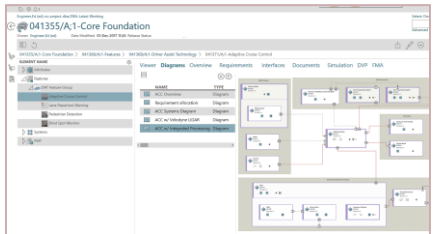
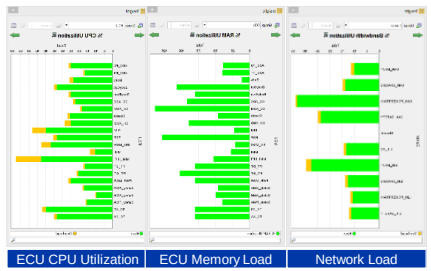


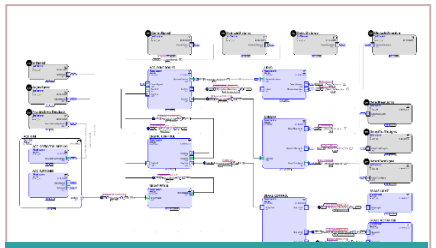
Multi-Domain System Model

5

Domain Metrics



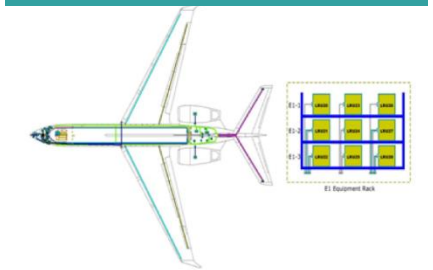
Physical Metric Forecast (Space, Cost, Weight, Length)
Software Metric Forecast (RAM/ROM/FLS, Performance)
Network Metric Forecast (Load), Design Rule Checks



E/E Function Architecture

2

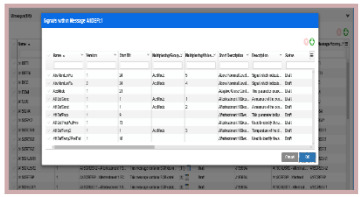
E/E Platform Architecture



Logical Architecture
Physical Architecture (⇔ NX)
Network & Ground Carriers

Network Signals
Electrical Signals
SW Signals

IO Hardware
Power Distribution



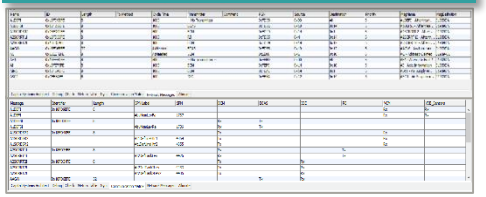
Signal IO

6

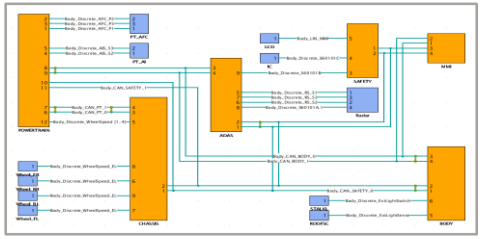
Multi-Board System Design

PCB Design 7

Networks & SW Architecture



Capital Network AUTOSAR & Network Design 7



Electrical - System Logic

Capital Design Electrical Implementation 7

Physical Implementation

Generative & Connected Engineering for the Product Lifecycle
Models, Constraints in Agile development

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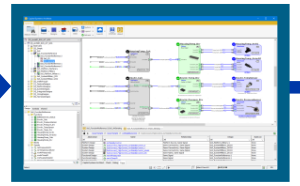
Integrated with both MCAD and PLM / ALM Systems

Systems & Requirements

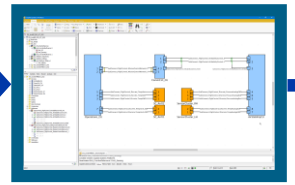
Continuous Digital Thread

Capital Portfolio

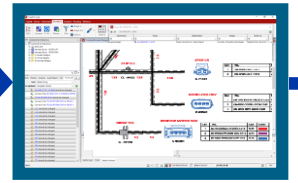
Normalize **Functional Models** in Capital



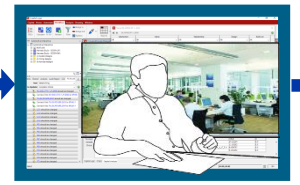
Extract Discreet **Logical Systems**

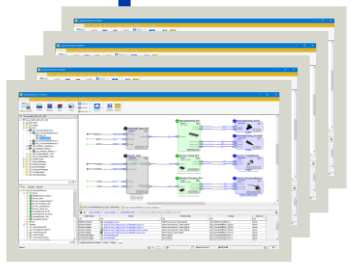


Extract Discreet **Harness Designs**

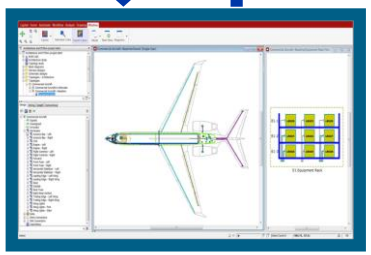


Extract & Publish **Electrical Service Data**



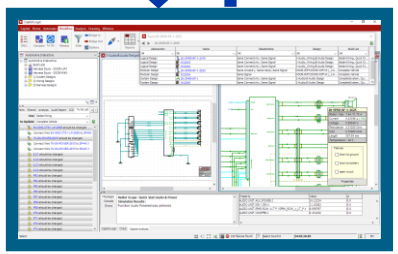


Multiple sources of **Functional** Models
(SysML, Visio, Excel…)



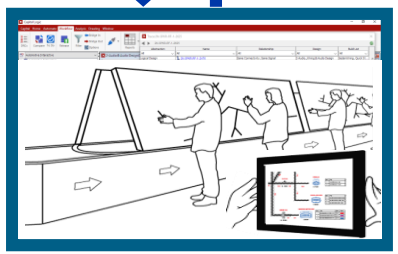
Generate **Architectures** for Logic, NW, HW, SW

DEFINE Domain



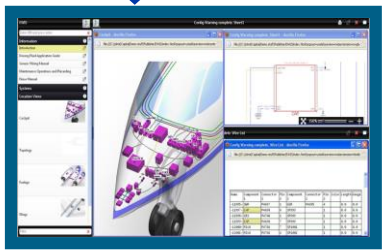
Generate **Electrical Distribution** System

DESIGN Domain



Generate **Manufacturing BoP, Costs & Aids**

PRODUCE Domain



Generate **Service Documentation**

MAINTAIN Domain

Supported by both In-Tool and External Verification & Validation

Connected Engineering for the Electronic MBE

A portfolio of tools support the entire electrical engineering life cycle

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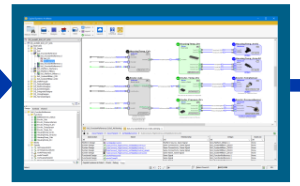
Integrated with both MCAD and PLM / ALM Systems

Systems & Requirements

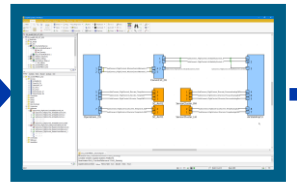
Continuous Digital Thread

Normalize **Functional Models** in Capital



Multiple sources of **Functional** Models
SysML, Visio, Excel…)

Extract MB-BoF
Electronic SubSystem

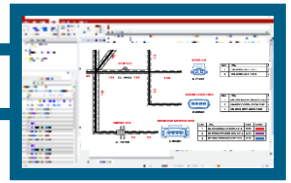


Generate **Architectures** for Logic, NW, HW, SW

Capital Architect

Extract Harness Definition
Harness Designs (ICD)

Capital Devices



Generate Electronic Distribution System

System Designer

Generate **MB Logic Representation**

Designer

Generate **Physical Implementation**

Layout

Supported by both In-Tool and External Verification & Validation

Shows roadmap, which are items are statements of intent, no firm commitments and may change without prior notice

Capital – Supporting the Model Based Enterprise

A portfolio of tools support the entire electrical engineering life cycle

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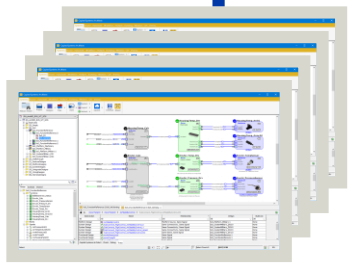
Sourced from and integrate-able with PLM / ALM systems

Systems & Requirements

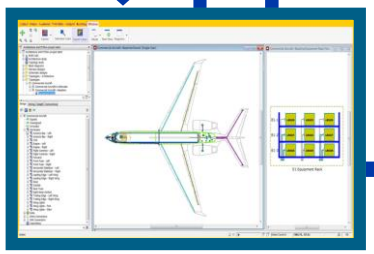
Continuous **Digital Thread**

Capital Portfolio

Normalize Functional Models within Capital



Multiple sources of **Functional** Models (SysML, Visio, Excel…)



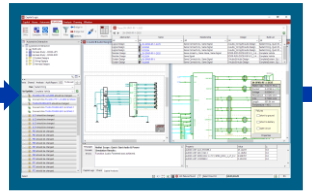
Generate **Architectures** for Logic, NW, HW, SW

DEFINE Domain

Software Components

Avionics Networks

Roadmap



Electrical Distribution

DESIGN Domain

Manufacturing Solutions

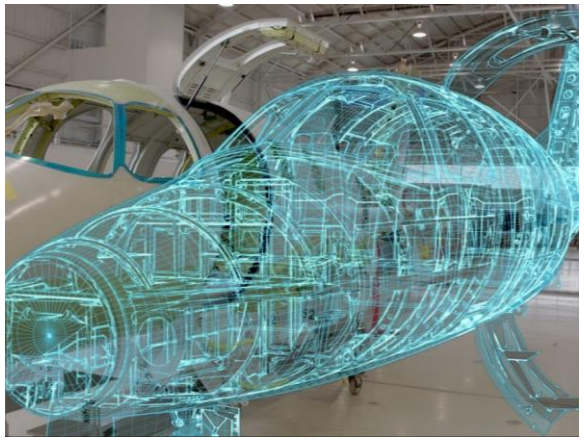
PRODUCE Domain

Service Solutions

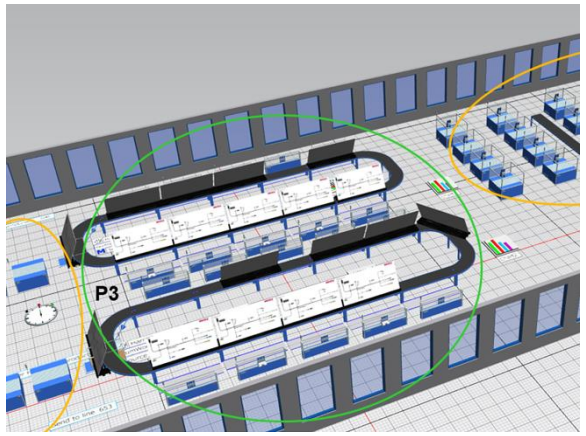
MAINTAIN Domain

Supported by both in-tool and external Verification & Validation capabilities

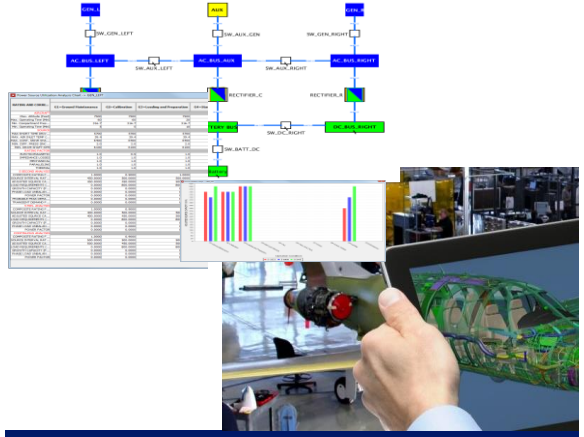
Creating the Electrical, Configuration Controlled, Digital Twin



Digital Twin of the Product



Digital Twin of Production

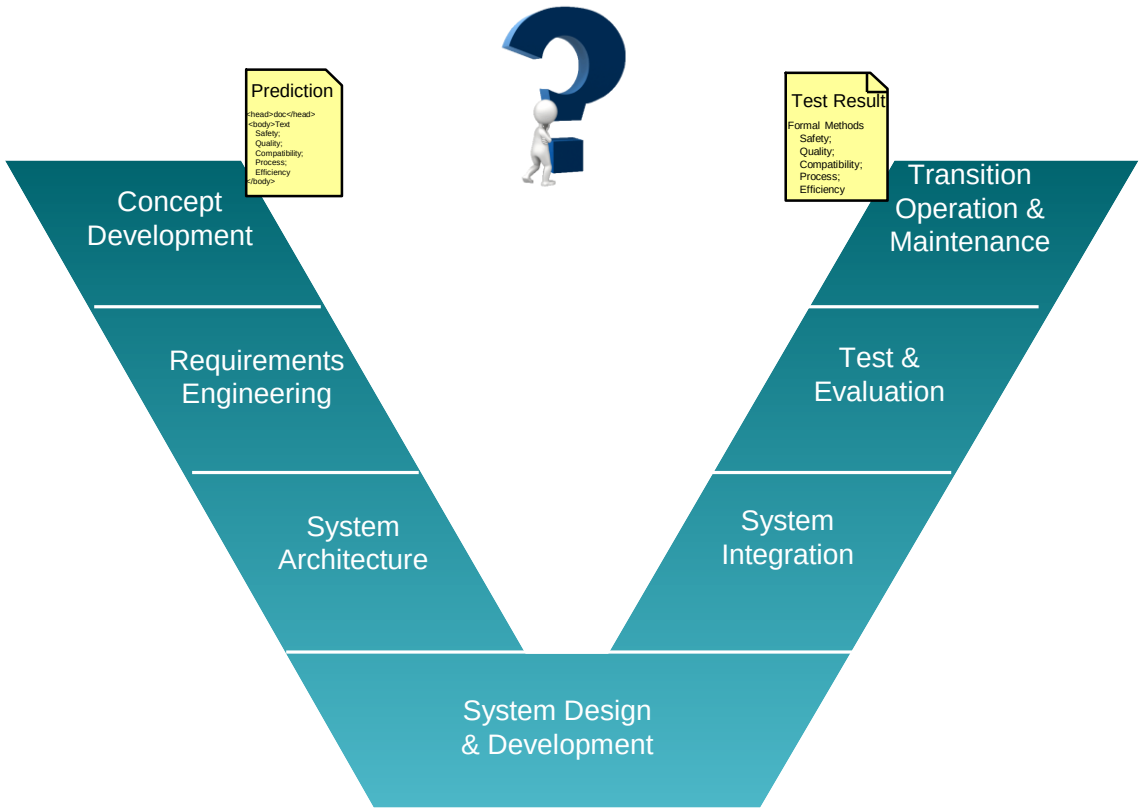


Digital Twin of Performance

Connected by a comprehensive DIGITAL THREAD

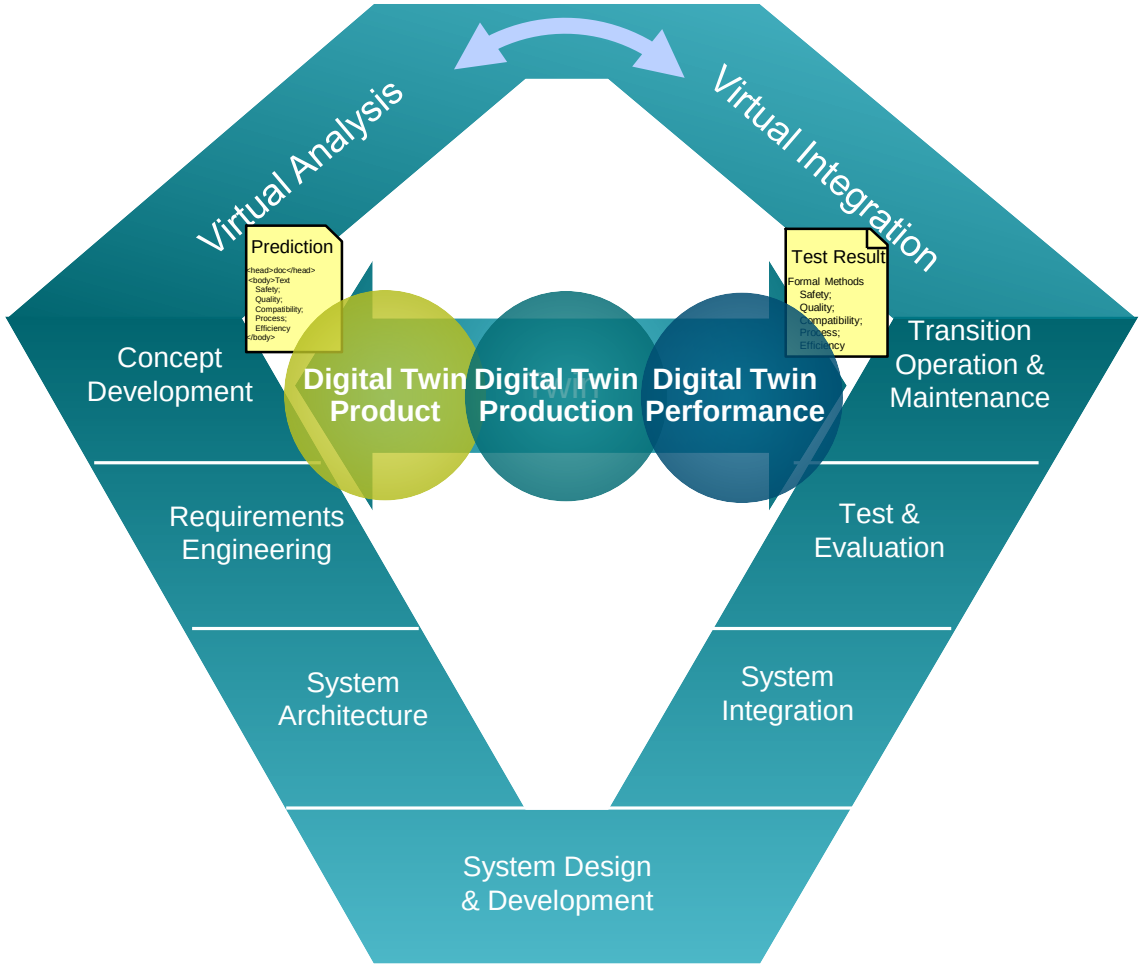
How can we use this?

Closing the Loop in Bridging MBSE and MBD



- **Conceptual design and requirements derive predicted results**
- **Test and Evaluation provide actual characteristics**

Closing the Loop in Bridging MBSE and MBD



- **Conceptual design and requirements derive predicted results**
- **Test and Evaluation provide actual characteristics**
- **Interrogating the Digital Twin(s) reveals the match / differences**

Address the impact of electrical complexity on compliance

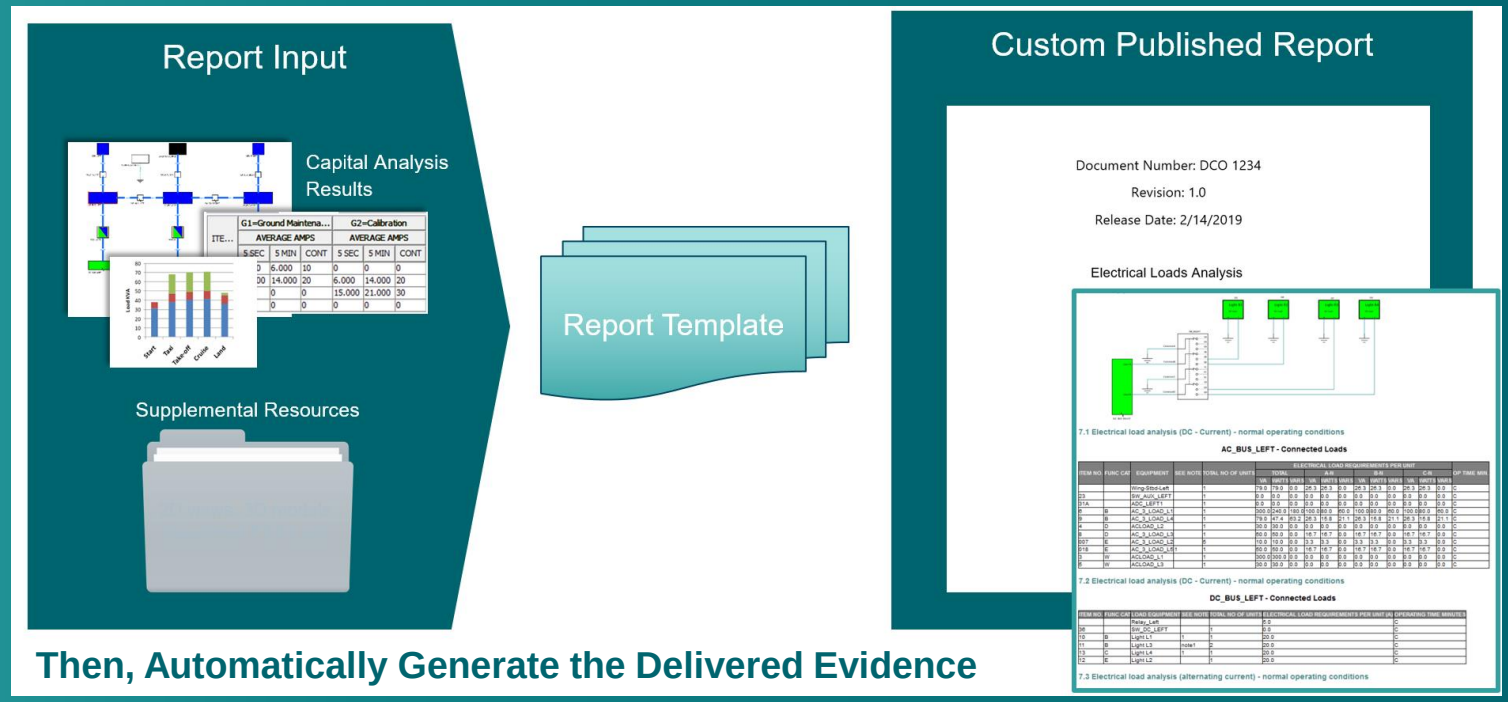
Accurate Verification: Scalable, Automated and Continuous

Exploiting the configuration-controlled digital twin

Comply by construction via constraints and automation

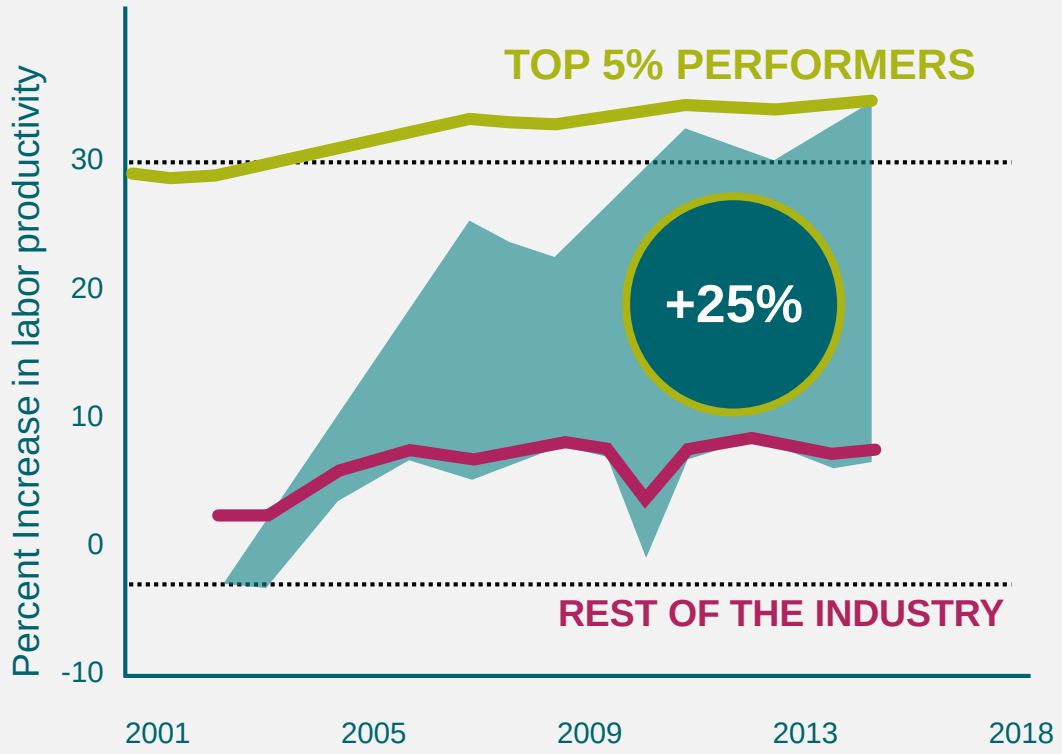
Continuously verify design compliance

Check it, analyze it, virtually verify it - as you design it!



Those who adapt & lead, DOMINATE.
The widening gap in digital productivity

Global Product Data Interoperability Summit | **2019**



Data is from 24 OECD countries.

The top 5% of companies are dominating the economy by exploiting digital competencies

The Best Versus the Rest: The Global Productivity Slowdown, Divergence Across Firms And The Role of Public Policy, OECD Productivity Working Papers

Aerospace Companies Who Have Made the Change
And Are **Reaping** Quantifiable Benefits Today

Reduce platform weight to increase payload capacity

Optimized by integrating electrical and MCAD design, orchestrated by integration with Teamcenter

"keeping our products ahead of the market requires the creation of intimate connections between avionics and other aspects of the aircraft, such as mechanical systems"

Pilatus

Increase efficiency with an improved electrical process

Modern Helicopters have complex wiring interconnections

20% reduction in wiring system design time compared with previous norms

"Capital gives a substantial productivity boost … tools are easy to use, with superior automation, and ensure high level of data correctness"

KAI

Transform business process with better design systems

Architected the electrical system using generative design.

Merged systems definition with packaging requirements, reducing downstream design cycles

Bell Helicopter were able to significantly streamline their wiring design processes on the Bell 525 Relentless program

Bell

Enterprise commitment to the digital thread

Organizational transformation via automation & digitalization.

Meet the challenges of next gen electrical design & manufacturing.

"Our partnership with the Siemens team will combine **best-in-class electrical design tools** with Boeing's vast experience and knowledge in our 2CES transformation of electrical design"

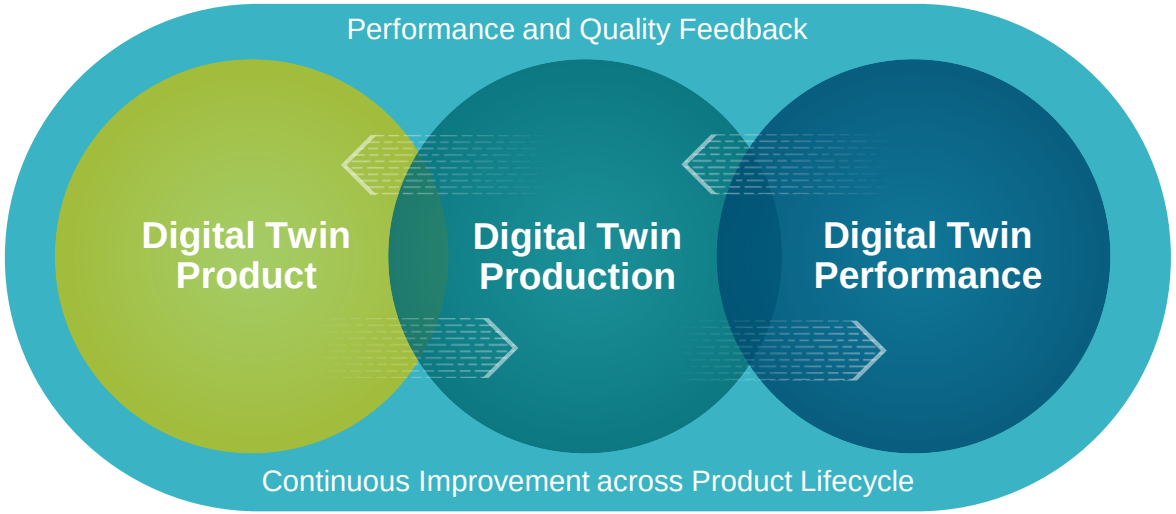
Boeing

Participate in the Ecology of Industry Leaders

By Bridging Model Based Systems Engineering & Model Based Design

Thank You!

Appendix


Performance and Quality Feedback
Digital Twin Product
Digital Twin Production
Digital Twin Performance
Continuous Improvement across Product Lifecycle

Systems Engineering: Holistic Product Development

The Industry's Most Comprehensive Solution Portfolio

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